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Liquefied petroleum gas monitoring and leakage detection system using nodemcu ESP8266 and wi-fi technology

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ABSTRACT

Liquefied Petroleum Gas which is popularly known as LPG is a clean source of energy which is highly flammable and usually compressed into storage tanks. Due to the flammable nature of LPG it can easily lead to uncontrollable explosions in the presence of any ignition action or may lead to complete depletion of oxygen in a particular area. This study is focused on the fabrication of a system that would detect, monitor and control LPG gas leakages for domestic gas cylinders. A MQ-2 gas sensor was used for the detection of LPG gas leakages, the monitoring aspect was satisfied locally through notifications triggered by LEDs, piezo buzzer and remotely through the use of an application known as Blynk. The control aspect was implemented with the use of a stepper motor which turns off gas cylinder regulators whenever gas concentrations are high. All operations are primary hinged on the NodeMCU ESP8266 controller and Wi-Fi communication technology.

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1. INTRODUCTION

LPG was first produced by Dr. Walter Snelling in the year 1910, making use of propane, butane and other saturated and unsaturrated hydrocarbons making the gas to be highly combustible [1-3]. LPG has a high calorific value because it burns completely and generates little or no smoke or soot [1]. That is why LPG gas is a very clean form of energy and prevents air pollution in our environment [2]. LPG can assume either a liquid or gaseous state depending on its exposure to the atmosphere and could lead to conditions such as asphyxiation, which has to do with the displacement of the surrounding oxygen which leads to suffocation, prolonged sleeping or fainting, discomfort or irritation to the respiratory tract, nose and eyes [2-3]. In terms of odour or smell LPG is odourless but an odorant (i.e. a chemical with a pungent smell) called Ethanethoil is added to the gas to make it easily detectable by the human sense of smell or a gas detection sensor [1, 4]. LPG is used for various applications such as for domestic fuel, industrial fuel, automobile fuels, in refrigerators and many more and is usually preserved in compressed air tight steel vessels [2-3]. These vessels are meant to be kept in environments at room temperature or less to prevent any form of explosion which is caused when the surrounding temperature exceeds the gas vapour pressure of these storage vessels [2, 5].

Wi-Fi is a wireless networking technology which does not use any form of a physical connection to act as a link between two or more communicating devices [5]. Wi-Fi technology makes use of radio waves which is within the electromagnetic spectrum as the form of connection between or among devices [6]. Wi-Fi

is owned by an organization known as Wi-Fi Alliance and this organization terms "Wi-Fi" as a registered trademark. Wi-Fi Alliance describe Wi-Fi as any Wireless Local Area Network (WLAN) product that has its standard based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11x standard [6-7]. Wi-Fi was previously a wireless Ethernet which was based only on 802.11b standard for WLAN, before the Wi-Fi Alliance included all WLANs whose standards are based on IEEE 802.11x standard and this led to the inclusion of 802.11a, 802.11g, dual band etc. [5-6].

Safety plays a significant role in determining how we interact with our environment but this safety is not always achieved to the maximum satisfaction as a result of what we do and use in our daily endeavours. Nowadays, the use of LPG gas has displaced other forms of fuels like coal, firewood, etc., that we make use of, due to the fact that it is a clean source of energy [1-2]. Despite this advantage, the use of LPG gas is accompanied with a high level of risk because of its flammable and combustible nature which enables it to diffuse and burn easily even at a significant distance from its main source whenever it leaks [3]. Leakage of LPG gas can lead to uncontrollable fire explosions and asphyxiation when the leakage is not detected and controlled on time [2-3].

In the year 2012, Malaysia recorded about 2,089 gas explosions and in the year 2013, a record of about 2,019 gas explosion occurred which was a slight decrement of about 3.4% [8]. Although, there was a slight decrease in the incidents of gas explosions between the year 2012 and 2013, gas explosion still continues to be a major concern through the continuous unpleasant occurrences which leads to severe injuries, loss of lives and properties. Also, according to the Fire and Rescue Department Malaysia (FRDM) Director-General Datuk Wan Mohd Nor Ibrahim stated that an average of about 6,000 incidents of fires are being recorded on annual basis from the year 2014 through 2016, of which about 2,400 incidents are associated with domestic fires which are usually as a result of LPG gas leakages and this constitutes about 40% of the annual fires recorded in Malaysia [9].

In order to retard this effect, this paper presents a Liquefied Petroleum Gas Monitoring and Control System Using NodeMCU ESP8266 and Wi-Fi Technology which employs the use of a MQ-2 gas sensor which is calibrated into three sensing levels of low, moderate and high concentration for the detection of LPG gas leakages. A local and remote form of monitoring was also implemented through the use of LEDs, piezo buzzer and a mobile application known as Blynk respectively. A control mechanism was put in place by the use of a stepper motor which turns off the gas cylinder regulator whenever the gas concentration is high. The NodeMCU ESP8266 acts the central control of the system having programmed instructions through the use of Arduino IDE and leveraging on Wi-Fi technology. The implementation of this system would go a long way in reducing the rate of sudden gas explosions and ensuring the security of lives and properties.

2. RELATED WORKS

There are various kinds of gas detection, notification and control systems in existence, some of which are highlighted in this section.

2.1. Gas Detection and Notification Systems

Indhuja and colleagues [10], made a Smart System for Hazardous Gas Detection with the use of various gas sensors ranging from MQ-2 to MQ-7, for the detection of various harmful gases such as methane, hydrogen sulphide, carbon monoxide and ammonia gas present in the atmosphere at any particular instance. The notification mechanism implemented was the use of a software known as Arduino IDE serial monitor. This system is reliable, cost effective and offers accurate results as far as detection and notification of users is concern. The system also offers safety to the users through its wireless connectivity because a user can monitor or receive notification through the use of the Arduino IDE serial monitor at a significant distance from the source of gas being monitored. K. Padma and others [11], fabricated a Smart Gas Cylinder Using Embedded System by using MQ-6 gas sensor and also put in place two forms of notification mechanisms which were made to detect the presence of LPG and monitor the weight of the LPG in the gas cylinder, by a GSM module which sends SMS messages and an LCD display as notification mechanisms. This system offers a high level of reliability with its dual form of notifications and makes use of ZigBee and GSM technology as a connectivity for the LCD display and SMS messages respectively.

V. Hazarathaiah and colleagues [1], made use of the same gas sensor as well as the dual notification features implemented by K. Padma et al [11] to develop a Gas Leakage Detection and Control System and achieved the same results. Leavline et al [12], made use of MQ-6 gas sensor for detection of LPG gas concentration and implemented a slightly different dual notification features for their design of LPG Gas Leakage Detection and Alert System. The dual form of notification used was a buzzer for an audible alarm and LEDs for a visual notification which is very reliable and cost effective but renders notifications for only a limited range. Just as Hazarathaiah et al [1], V. Ramya et al [13] also made use of two forms of notifications

which includes the SMS messages and LCD display. They all had the same sort of results for monitoring the gas leakage at a far and near distance with high reliability. Mahesh et al [14], made an LPG Leakage Detection and Control System by Using Microcontroller with a MQ-6 gas sensor for the gas detection and two forms of notification mechanisms which included an LCD and a buzzer. Although the system is durable, reliable and cost effective, unlike that made by Ramya et al [13], this system cannot alert users at a significant distance.

Hossain and colleagues [4], implemented a Matlab Guidance Based Smart Gas Leakage Detection and Security System Using Analog to Digital Technique and made use of MQ-5 and three features in place for notification purposes. These notification features included an audible alarm through the use of a buzzer and two visible means, via an LED and an LCD display. The notification features found in this system are suitable for users who are not far from the system. S. Rajitha et al [15], fabricated a Security System Using GSM for Gas Leakage with the use of MQ-5 gas sensor for the detection of LPG gas and three means of notifications that included two visible means, via the use of LEDs and SMS messages with an audible alarm through a buzzer. This system is very reliable and cost effective, offering variation in notifications which could act as a backup in situations where one fails and also renders alert to the user about safety issues irrespective of the distance. A Cylinder LPG Gas Leakage Detection for Home Safety was implemented by T. Soundarya et al [2] with an MQ-6 gas sensor for the detection of LPG and also made notification in three forms, just like that made by S. Rajitha et al [15], but used an LCD display in place an LED. Nadu et al [16] made a Control and Monitoring System for Liquefied Petroleum Gas Detection with the same outcome as that of T. Soundarya et al in terms of detection and notification mechanism through the use of MQ-6 gas sensor with a GSM module and an LCD display respectively. The result of both were similar and reliable.

Similar systems as that made by T. Soundarya et al [2] and Nadu et al [16] for detection and notification, with similar outcomes were also implemented by others. Some of these systems include a Design and Development of an Automated LPG Monitoring and Pre-paid Billing System made by Charan et al [17], a Gas Leakage Detection and Control System made by Srinvasan et al [18], a GSM Based Gas Leakage Detection System with Preventive Measure made by Tanvira et al [19], a LPG Gas Monitoring System made by Arun et al [20], a LPG Gas Weight and Leakage Detection System Using GSM made by Sameer et al [21], a Microcontroller Based Gas Leakage Detection and Automatic Shut-off System made by Divyanshu et al [22], a Smart Gas Booking and LPG Leakage Detection System made by Halavva et al [23] and an Automatic LPG Booking, Leakage Detection and Real Time Gas Measurement Monitoring System made by Jolhe et al [24].

Huan et al [25] made use of a MQ-9 gas senor for the detection of carbon monoxide (CO) and methane (CH4), and implemented four notification features that include an audible alarm, a LabVIEW Graphic User Interface (GUI), an LCD and LEDs for their Design and Development of Gas Leakage Detection System Using Arduino and ZigBee. This system is very efficient in notifying users both far and near with real time records of gas concentration levels. As the system made by Huan et al [15], Nithiya et al [26], made a Gas Leakage Monitoring and Control Using LabVIEW which makes use of MQ-2 gas sensor for the detection of LPG gas and also implemented similar notification features with the exception of an LCD display. The system is reliable and offers notification for users both far and near as well as real time record of gas concentration levels just as that made by Huan et al.

2.2. Gas Leakage Control Systems

A gas control system was implemented by Rajitha et al [15] through the use of an exhaust fan which works in such a way that whenever there is a gas leakage detected by the gas sensor, the exhaust fan is immediately triggered to help extract the available gas concentration within that particular area. This gas leakage control system is very efficient and highly suitable for indoor gas users such as households and industries. Some other gas control systems such as that made by Huan et al [25], Tanvira et al [19], Arun et al [20], Padma et al [11], Halavva et al [23], and Jolhe et al [24] made use of an exhaust fan as their primary control mechanism as that made by Rajitha et al [15]. All their gas leakage control systems worked in a similar way with regards to gas control which involves 'throwing' the leaked gas from a confined location in order to reduce the gas concentration level low so as to prevent possible gas explosions. Unlike the gas leakage control system made by Rajitha et al [15], Charan et al [17], didn't make use of an exhaust fan but made use of gas cylinder regulator controller which automatically turns off the gas cylinder regulator whenever there is a gas leakage being detected by the gas sensor. This system is very effective as long as gas control is concerned because it requires no direct contact with the user in order to prevent continuous gas leakage. Nithiya et al [26] made a gas cylinder regulator controller just like that of Charan et al [17], but implemented the services of a solenoid valve which aids to turn off gas regulator when there is a gas leakage. The controller mechanism used by Nithiya et al [26] is very reliable and cost effective. Divyanshu et al [22], made use of a servo motor to replace the solenoid valve which acts a gas cylinder regulator controller used

Charan et al [17] and achieved them sort of result of switching off the gas cylinder regulator by turning it at an angle of 180 degrees when a leakage is sensed. This gas leakage control system also possesses a fully automated control mechanism.

Soundarya et al [2] designed a gas leakage control system with two control mechanism which involves the use a DC motor control knob which is made to automatically turn off gas cooker regulator whenever there is a leakage and also the use of an exhaust fan to throw away the leaked gas in the area of the sensed gas. A similar system was fabricated by Nadu et al [16] with only difference being the placement of DC motor control knob. Unlike Soundarya et al [2], Nadu et al [16] placed the control knob to turn off the gas cylinder regulator rather than the gas cooker regulator when there is a gas leakage. Both systems are highly efficient in gas controlling because of the two varieties of techniques been put in place. Just as Soundarya et al who implemented two control features for their gas control system, Srinvasan et al [18] also implemented two control features for their system which also involves the use of an exhaust fan and solenoid valve for throwing of leaked gas and turning off gas cylinder regulator respectively in any occurrence of gas leakage [12], [18]. A similar system which works in the same manner in the aspect of gas leakage controlling as that of Srinvasan et al [18] was developed by Hazarathaiah et al [1]. Both of the systems work in a fully automatic mode in the aspect of gas leakage control with high level of reliability as well as performance. An improvement to the gas leakage control system developed by Srinvasan et al [18] and Hazarathaiah et al [1] was done by Mahesh et al [14] who made an addition control mechanism to the exhaust fan which 'throws' leaked gas away and the solenoid valve that turns off the gas cylinder regulator by implementing a magnetic lock that locks all windows to prevent the diffusion of the leaked gas to neighboring places and also an automatic off switch which turns off all electrical appliances in order to prevent any form of spark that can lead to an ignition action which could result to a severe gas explosion and fire disaster. This system is fully equipped with control mechanisms that could effectively mitigate any form of possible gas explosions and could be deployed in household and industries to improve the level of safety in such vicinities.

3. RESEARCH METHOD

Figure 1 shows the operation of the system. When there is a gas leakage, the gas sensor detects the gas leakage which is made possible by the gas sensor which has been calibrated with the NodeMCU ESP8266 into three sensing levels. The sensing levels include the LOW, MODERATE and HIGH gas concentrations for ranges between 0-250ppm, 250-300ppm and above 300ppm respectively. The gas that is detected by the gas sensor is an analogue signal and such signals are converted into digital signals by aid of the NodeMCU ESP8266. When the gas concentration is LOW, the green LED on the main hardware is turned ON as well as the green LED on the Blynk application with a message on the LCD and its concentration on the gauge. When the gas concentration is MODERATE, the yellow LED is turned ON as well as the yellow LED on the Blynk application with a message on the LCD and its concentration on the gauge. When the gas concentration is HIGH, the red LED and the buzzer on the hardware are turned ON as well as the red LED on the Blynk application with a message on the LCD and its concentration on the gauge. Also, when the gas concentration is HIGH, the stepper motor is triggered to rotate the attachment to its shaft which helps to serve as a controller which turns OFF the gas cylinder regulator in order to prevent further leakage of the gas.

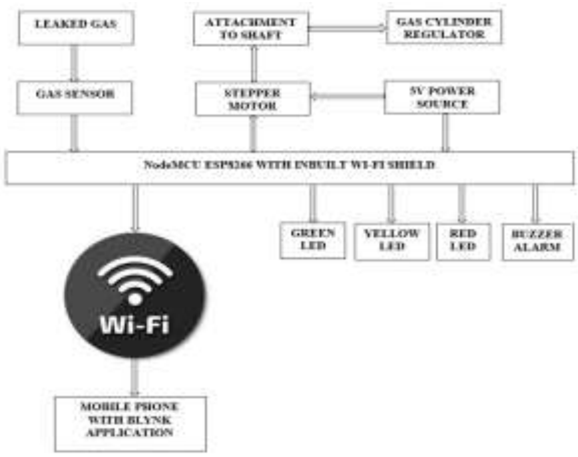


Figure 1. Block Diagram of system

3.1. Design Models

This section highlights the various design models which were fabricated to satisfy the objectives in this study which include to detect the presence of LPG leakage, to notify users of gas leakage and to control further gas leakage.

3.1.1 LPG Detection Model

This model consists of a MQ-2 gas sensor and a controller in the form of a NodeMCU ESP8266. This model incorporates both the services of hardware and software, with the hardware aspect dealing with physically interfacing of the MQ-2 gas sensor to the NodeMCU ESP8266 and software aspect dealing with calibration of the gas sensor through the use of Arduino IDE software. Through the use of this software, the desired code was uploaded into the NodeMCU ESP8266 to calibrate the analogue signal which the MQ-2 gas sensor detects and converts it into a digitalized form for easy reading. The MQ-2 gas sensor was calibrated into three varying levels, the LOW, MODERATE and HIGH gas concentrations for ranges between 0-250ppm, 250-300ppm and above 300ppm respectively.

3.1.2 Notification Model

The notification model was designed into fixed notification model and movable notification model. The Fixed Notification Model was attached to the detection model making it to be unmovable. The fixed notification model is comprised of three LEDs (i.e. green, yellow and red) and a buzzer which are connected to the NodeMCU ESP8266 to produce the predetermined outputs. The calibration of the MQ-2 gas sensor is interpreted via the LEDs as well as the buzzer. When the concentration gas concentration is LOW, MODERATE or HIGH the green, yellow and red LEDs are turned on respectively. In addition, the buzzer is triggered when the red LED is on. The movable Notification Model was designed in the form of an application known as Blynk which could be installed on mobile phones to continuously monitor gas status and offers the flexibility of mobility, regardless of the distance from the device (NodeMCU ESP8266) as long as it is connected to a Wi-Fi connection. The movable notification model also works in a like manner as the fixed model displaying the three levels of gas leakages of LOW, MODERATE and HIGH with similar set of LED colours with the inclusion of a virtual LCD which displays various warning messages and a virtual gas gauge which shows the digitalized form of the gas leakage level both in figures as well as the gradients.

3.1.3 LPG Leakage Control Model

This model consists of a stepper motor and a motor driver (A4788) connected to the NodeMCU ESP8266 which acts a controller for the desired response. Based on the design concept, the NodeMCU ESP8266 is programmed to trigger the stepper motor which has an attachment to its protruding shaft to act as a form of obstacle blocker in order to rotate the gas regulator knob to an off position. This action of the rotation of the stepper motor to turn off the gas regulator knob is initiated when the gas leakage is HIGH which associated with any gas concentration level above 300ppm.

4. RESULTS AND ANALYSIS

The various design modules of the liquefied Petroleum Gas Monitoring and Leakage Detection System Using NodeMCU ESP8266 and Wi-Fi Technology are outlined and discussed. The critical analysis and the various results recorded for the various models of the system which include the following LPG detection model, notification model and LPG leakage control model.

4.1. LPG Detection Model

This Model which involves the use of the MQ-2 gas sensor and NodeMCU ESP8266 which are primarily tasked with the detection of LPG gas in a particular confinement. The gas sensor which is very sensitive to LPG gas and also has a null sensitivity in clear air was successful used in the detection of LPG gas in this study. The Arduino IDE software which was used to calibrate the MQ-2 gas sensor was also implemented to show the varying gas concentration levels in a digitalized form.

Figure 2 shows the MQ-2 gas sensor detection sensitivity which usually varies with respect to either an increase or decrease in gas concentration in part per million (ppm) of the leaked gas. It was also observed that the sensitivity of the gas sensor is also dependent on the proximity of the gas leakage source.

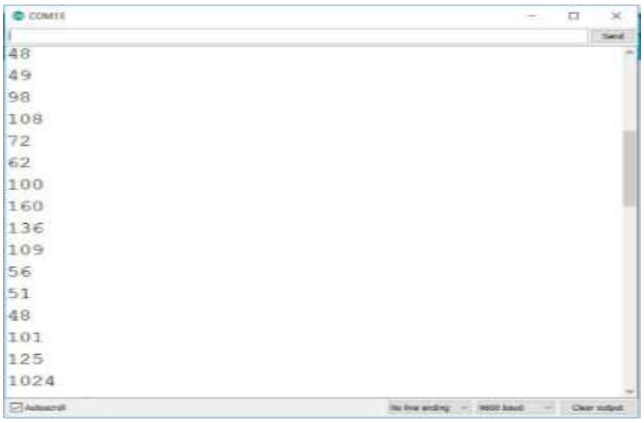


Figure 2. Arduino IDE Serial Monitor displaying varying gas concentrations (ppm)

4.2. Notification Model

This model is divided into two distinct models, consisting of a fixed notification system and a movable notification system.

4.2.1 Results of Implementation of the Fixed Notification Model

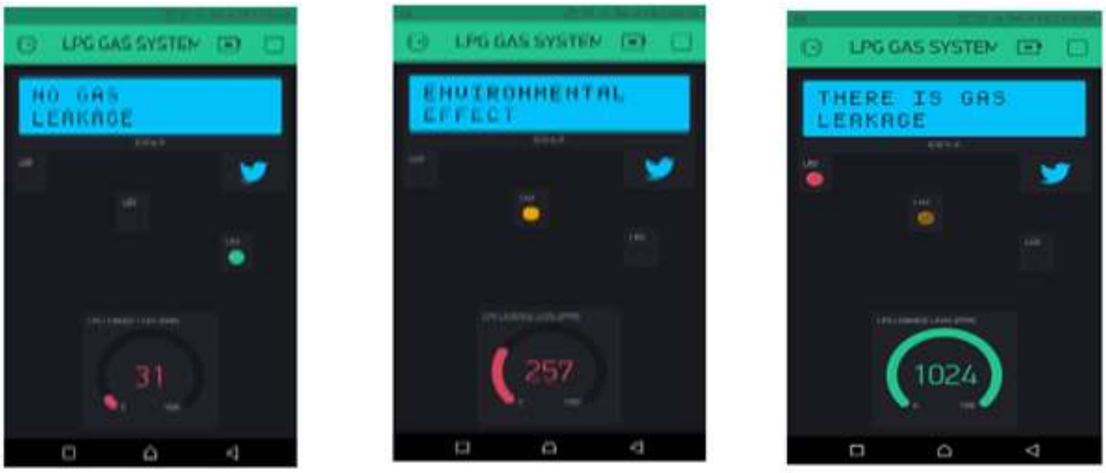
The fixed notification model offers three distinct results which depends on three scenarios, which are based on the calibration been made to the MQ-2 gas sensor. The calibrations which involves three separate gas leakage concentration levels termed as LOW, MODERATE and HIGH with gas concentration ranges of 0ppm to 250ppm, 251 to 299ppm and above 300ppm respectively. All the outcome of the three scenarios are shown in Figure 3.

(a). Low gas concentration (b). MODERATE gas concentration (c). HIGH gas concentration

Figure 3. Notification of gas concentration

4.2.2 Results of Implementation of the Movable Notification Model

The movable notification model was made possible through the deployment of the mobile application known as Blynk. It’s operation and performance was also based on the three scenarios of gas concentration levels of LOW, MODERATE and HIGH with the same gas concentration ranges as that used for the fixed notification system model. Figure 4a) shows the Blynk interface display for LOW gas concentration, which involves the LCD displaying a warning message stating “LOW GAS LEAKAGE”, with the green LED Lighted and the digital gauge displaying the concentration of the gas in parts per million (ppm). The Figure 4b) shows the Blynk interface display for MODERATE gas concentration, which involves the LCD displaying a warning message stating “ENVIRONMENTAL EFFECT”, with the yellow LED Lighted and the digital gauge displaying the concentration of the gas in parts per million (ppm). The Figure 4c) shows the Blynk interface display for HIGH gas concentration, which involves the LCD displaying a warning message stating, “THERE IS GAS LEAKAGE”, with the red LED Lighted and the digital gauge displaying the concentration of the gas in parts per million (ppm).



(a). BLYINK Notification for LOW Gas Concentration

(b). BLYNK Notification for MODERATE Gas Concentration

(c). BLYNK Notification for HIGH Gas Concentration

Figure 4. Blynk notification of LOW, MODERATE and HIGH gas concentration

4.2.3 LPG Leakage Control Model

The LPG leakage control model was implemented through the use of a stepper and a suitable attachment to its shaft which acts as an obstacle removal in the path of the stepper motor when it rotates. The leakage control mechanism is always triggered when the gas concentration is high.

Figure 5 shows the action taken by the system when the concentration is high, which involves turning on the red LED, an alarms as well as triggering the stepper motor to rotate in a clockwise motion in order to off the gas cylinder regulator.

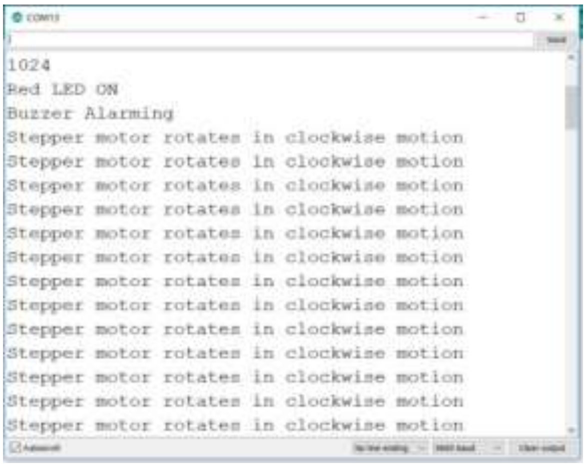


Figure 5. Arduino IDE serial monitor display of action of control model

5. CONCLUSION

This paper implemented three design models to fulfil the objectives of the study. The first objective which is to design a system that can detect the presence of LPG gas was achieved through the implementation of the LPG detection model and also through literature review. The second objective which is to design a system that can give visible and audible notification both locally and remotely was achieved through the implementation of the notification model as well as some literature review. The final objective which is to design a system that will prevent further gas leakage was also realized through the implementation of the LPG leakage control model. The final prototype fabricated was fully functional and had the capability to detect, monitor as well as control LPG leakages from LPG storage tanks

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